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ZINC UPTAKE AND ACCUMULATION IN RECOMBINANT INBREED LINES OF RICE (*ORYZA SATIVA L.*) UNDER VARIED ZINC LEVELS

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ABSTRACT

In the present study, the effect of different levels of zinc on growth and zinc uptake was analysed in contrasting zinc accumulating recombinant inbreed lines (RILs) developed in our laboratory and other genotypes. Plants were grown in zinc deficient soil (<0.65 ppm zinc) and the soil was supplemented with zinc fertilizer @ 10 kg/ha, 20 kg/ha and 40kg/ha. Phenotypic pattern and micronutrient accumulation such as zinc in different RILs and genotypes were analyzed, which grew under zinc deficient and supplemented conditions. The results revealed that the RILs performed well compared to genotypes under zinc deficient condition. The characteristic symptom of the genotypes under Zn-deficient conditions was found to be severe yellowing/bronzing of leaves. Further, scoring of panicle emergence index showed well exerted panicle in high zinc RILs, and delayed panicle emergence was observed in zinc deficiency susceptible genotype under both Zn deficient and supplemented conditions. No significant reduction in plant height was observed among RILs and genotypes. Increased grain yield and grain Zn accumulation was observed in RILs under zinc supplementation at 20 kg/h. These results indicate that RILs developed for high zinc accumulation were able to efficiently accumulate Zn, which was also correlated with high grain yield under Zn supplemented conditions as compared to other genotypes.

KEYWORDS: Rice (Oryza Sativa), Grain Zinc, Panicle Emergence Index, Zinc Accumulation & Symptom Score

Original Article

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INTRODUCTION

Zinc (Zn) is an important element, which is essential for protein synthesis in plants (Cakmak, 2000). About 10% of the proteins in the biological systems require Zn for normal functioning (Andreini*et al*., 2006) and is essential as cofactor for over 300 enzymes (Coleman, 1998). In addition to plants, zinc is an essential micronutrient required in human beings. Nearly, 1/3rd of the world population is affected by Zn deficiency, due to low dietary intake. In humans, zinc deficiency mainly causes DNA damage, reduction in growth and impairments in the immune system (Keen and Gershwin, 1990).

Cereal such as rice is a major source of Zn consumed among world population. However, zinc level in rice is generally low, and therefore, it is essential to increase the Zn content in crops to alleviate its deficiency in humans (Graham, 1984). About 30% of the soil is deficient (Alloway, 2004) in zinc around the world. In India more that 50% of the agricultural lands are found to have low levels of zinc for plant uptake, thus reducing grain Zn accumulation. Strategies to improve Zn concentration in rice grain is achieved through conventional breeding, fertilizer application and biofortification (Cakmak, 2008). Plant breeding strategy together with fertilizer management constitutes an effective approach in improving Zn content in rice grains.

Therefore, present study was conducted to determine the effect of different levels of soil zinc application to increase the grain Zn concentration, and also improve the plant growth in recombinant inbreed lines (RILs) with high and low zinc accumulating efficiency and other genotypes.

MATERIALS AND METHODS

The experiment was conducted at the research field at University of agricultural sciences, GKVK, Bangalore. Recombinant inbreed lines (RILs) were obtained from cross between Azucena (high zinc) x Moromutant (drought tolerant) parents. RILs such as such AM32, AM65, AM72, AM143, Tanu (traditional variety, low Zn) and BI33 (aerobic variety, moderate Zn) were used in the experiment, respectively. Plants were grown in plastic pots containing zinc deficient soil (<0.65 ppm zinc) and supplemented with zinc fertilizer @ 10 kg/ha, 20 kg/ha, 40kg/ha and 0 kg/ha served as control. Zinc fertilizer was applied to plants at basal, 20 days after sowing (DAS) and 45 DAS, respectively. NPK was applied @ 100:50:50 along with zinc. The experiment was arranged in a randomized block design (RCBD) with four replications. Zinc deficiency symptom scoring and panicle emergence index was recorded according to standard evaluation system for rice (IRRI, 1996). Phenotypic characteristics such as zinc deficiency symptom scoring, panicle emergence index, Plant height, grain yield was recorded during harvest. Grain Zn content collected from the RILs and popular genotypes grown under zinc varied levels was analysed using AAS (Atomic absorption spectrometry). Grain samples (0.5 g) were digested in a bi-acid mixture (HNO_3: $HClO_4$ = 4:1), and Zn concentration was determined by atomic absorption spectroscopy at wave length 213.9 nm. Zn content was calculated with the values obtained from standard samples and grain Zn content was expressed as mg/kg.

RESULTS AND DISCUSSIONS

The primary characteristic reaction of the RILs and genotypes under Zn-deficient conditions was severe yellowing/bronzing of leaves. The genotypes such as AM65, Tanu and BI33 developed quite severe Zn-deficiency symptoms (score 5, height reduction and yellowing/bronzing), whereas AM32, AM72 and AM143 suffered only minor setback (score 3, yellowing). However, low symptom was observed under Zn supplemented conditions in all the genotypes except for Tanu which is low Zn susceptible variety. Further, scoring of panicle emergence index showed well exerted panicle in AM65 and BI33, moderately well exerted in AM65, AM72, AM32, however, enclosed panicle was observed in Tanu under both Zn deficient and supplemented conditions (Table 1).

Table 1: Zinc Deficiency Symptom Score and Panicle Emergence Index in Rice Grown under different Zinc levels

Sl No	Rice Lines	Zn @ 0 kg ha^{-1}		Zn @ 10 kg ha^{-1}		Zn @ 20 kg ha^{-1}		Zn @4 0 kg ha^{-1}	
		SS*	PEI**	SS	PEI	SS	PEI	SS	PEI
1	AM32	3	3	2	3	2	3	2	3
2	AM65	5	3	2	3	2	3	2	3
3	AM72	3	3	2	3	2	3	2	3
4	AM143	3	1	2	1	2	1	2	1
5	TANU	5	9	5	9	2	9	2	9
6	BI33	5	1	3	1	2	1	2	1

*Symptom score (SS): 1. Growth normal, healthy, 2: Basal leaves slightly discolored, 3: Stunting slight, basal leaves brown or yellowish, 5: Growth severely retarded, about half of all leaves brown or yellow.

**Panicle Emergence Index (PEI):1: Well exerted, 3: Moderately well exerted; 9: Enclosed

No much difference in plant height was observed among RILs and genotypes under different levels of zinc application. AM65 and AM32 were found to be higher under Zn supplemented conditions when compared to other RILs. Both the RILs showed significant reduction in plant height at Zn deficient condition when compared to Zn supplemented conditions (Figure 1). Plant height increased mainly at 10 and 20 kg/haZn application in RILs except for BI-33, which showed increased height at 40 kg/ha.

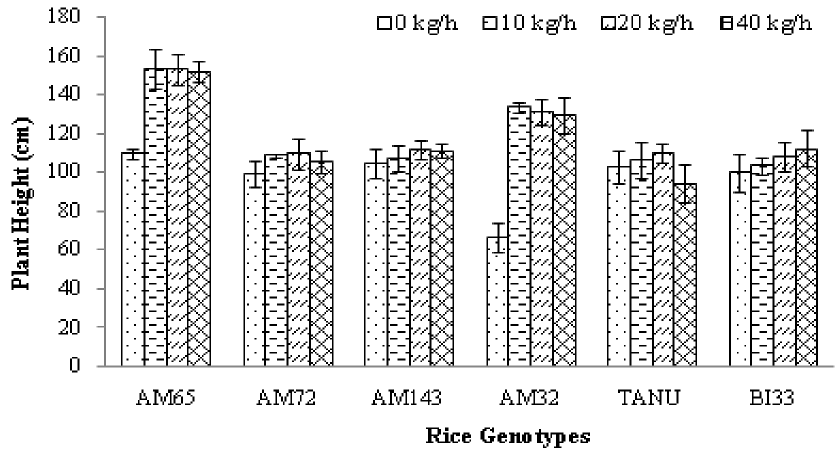

Figure 1: Plant Height of Rice Grown under Different Zinc Levels

Data points and error bars represent means ± SD of three replications each.

High grain yield was observed in AM143 (49 g) followed by AM72 (46 g), BI-33 (39 g) at 20 kg/ha, and AM32 (39 g) and AM65 (40 g) showed increased grain yield at 10 kg/ha Zn application (Figure 2). Grain zinc content was found to be high under Zn supplemented conditions as compared to Zn deficient conditions. Similar increase in grain yield due to Zn application in maize has been reported (Liu*et al*, 2016).

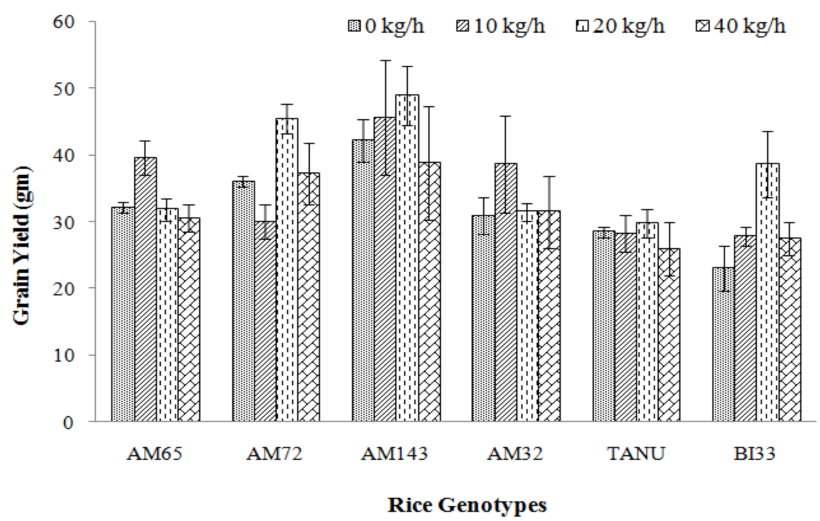

Figure 2: Grain Yield of Rice Grown under Different Zinc Levels

Data points and error bars represent means ± SD of three replications each.

Grain Zn content was higher in RILs (AM32, AM65, AM72, AM143) at 10 and 20 kg/h Zn levels, but was found to be low at 40 kg/h. The increase in grain zinc ranged from 1.5 to 3.5-fold. Not much Zn accumulation in grain was observed in Tanu under Zn supplied condition and was almost similar to Zn deficient condition (Table 2). This indicate that RILs developed for high zinc accumulation were able to efficiently accumulate Zn, which was also correlated with high grain yield under Zn supplemented conditions as compared to other genotypes. Previously, Cakmak (2002) reported that zinc content increase by as much as 2 to 3 folds in plants depends on type of plant species, soil zinc application and Zn accumulation efficiency. Grain zinc of high zinc accumulating variety increased nearly by 1 to 2 folds and in low zinc accumulating type by 1.16 folds.

Table 2: Zinc Content (mg/kg) in Rice Grain Grown under different Zinc Levels

Rice Lines	0 kg/h	10 kg/h	20 kg/h	40 kg/h
AM32	14.50±0.29	15.77±0.12	17.97±0.18	16.18±0.09
AM65	23.13±0.24	26.90±0.36	27.43±0.33	20.51±0.24
AM72	23.43±0.28	25.12±0.19	25.22±0.34	20.36±0.22
AM143	20.03±0.20	21.66±0.10	23.97±0.17	18.05±0.10
TANU	20.36±0.45	21.21±0.57	21.28±0.17	21.23±0.12
BI33	20.10±0.38	20.40±0.22	23.32±0.37	22.20±0.12

Data represent means ± SE of three replicates each.

CONCLUSIONS

In conclusion, the present study has shown that grain zinc in rice can be effectively increased through plant breeding along with soil zinc application. Further, it suggest that external zinc application is highly fast and effective practice in increasing grain zinc content, which provide both agronomic and nutritional benefits.

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